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A Dual Mode Converter Topology for Low Power Applications

[1]K.V.BINDU, [2]B.NAGARANI

[1,2] Assistant Professor, Dept of EEE, R.M.K. College of Engineering & Technology, India

Abstract: **This paper deals with the implementation of a converter, which allows transfer of power flow between the two dc sources in either direction. This converter can reverse the direction of flow of current, and thereby power, while maintaining the voltage polarity unchanged. The converter is the combination of two successful topologies, namely half bridge topology and current fed push pull topology. Both topologies are connected with high frequency isolation transformer. The primary side has the dc mains and the load, and the secondary side contains the battery to be charged and discharged. When dc main is present the converter operates in buck mode to charge the battery. On the failure of the dc main the converter operates in boost mode, where the battery regulates the bus voltage and provides power to the load. This bidirectional power flow is achieved by using same power components hence minimizing the hardware.**

Keywords: **Bidirectional dc-dc converter, boost mode, charging and discharging, current-fed push-pull topology.**

I. INTRODUCTION

Since electronic devices and many industrial applications require power from dc voltage sources. From ac supply systems, variable dc output voltage can be obtained through the use of phase-controlled converters or motor generator sets. The conversion of fixed dc voltage to an adjustable dc output voltage, through the use of semiconductor devices can be carried out by the use of dc-to-dc converters. The power semiconductor devices used for a converter circuit can be power BJT, power MOSFET, GTO, or forced commutated thyristor. These devices in general can be represented as a switch. When switch is off, no current can flow, when the switch is on, current flows. A bi-directional dc-dc converter is a vital part of standalone solar Photo-Voltaic (PV) systems [1] for interfacing the battery, space, telecommunication and computer systems. It allows transfer of power between two dc sources, in either direction. Due to their ability to reverse the direction of flow of current, and thereby power, while maintaining the voltage polarity at either end unchanged, they are being increasingly used in various applications [2] like dc uninterruptible power supplies, battery charger circuits, telecom power supplies and computer power systems. The drawback of lower efficiency can be eliminated by using transformers with high voltage ratio [3]. The bidirectional half-bridge/push-pull DC-DC converter and the bidirectional full-bridge/push-pull DC-DC converter are the other configurations [4]. The bidirectional fly back DC-DC converter is a simple and low-cost configuration [5]

II. SYSTEM ARCHITECTURE

This paper presents a bidirectional dc–dc converter topology for application as battery charger/discharger as shown in Fig1. The proposed converter is a combination of two well-known topologies, namely half-bridge and current-fed push-pull. The proposed converter provides the desired bidirectional flow of power for battery charging and discharging using only one transformer, as opposed to two in conventional schemes. It utilizes the bidirectional power transfer property of MOSFET’s. When the dc supply is present that will be given to the load as well as to the battery switching sequence signals and in absence of the dc supply the load will take the supply from the charged battery.

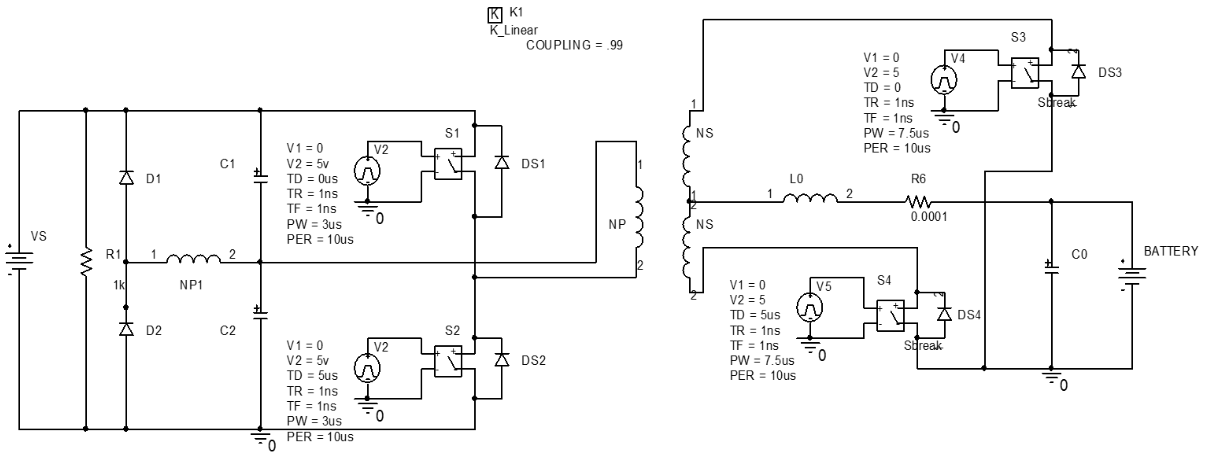

Fig. 1 Proposed dual mode converter

In the forward charging mode the switches S1 and S2 are turned on and operates a duty ratio less than 0.5 with the following switching sequence as shown in table 1.

Table 1. Switching Sequence of Switches S1 and S2

TIME PERIOD	S1	S2
$t_0 - t_1$	ON	OFF
$t_1 - t_2$	OFF	OFF
$t_2 - t_3$	OFF	ON
$t_3 - t_4$	OFF	OFF

Here we cannot use the switches S3 and S4. But we can use the diodes DS3 and DS4 for rectification purpose. In this bi-directional dc-dc converter we can use 100 kHz frequency, and then the time period is calculated.

T = 1/F, T = 1/100K = 0.01ms = 10us

Then the total time period = 10us , Duty Ratio = PW / PER , = 3/10 = 0.3 which is less than 0.5

Then the signal wave forms given in Fig2.

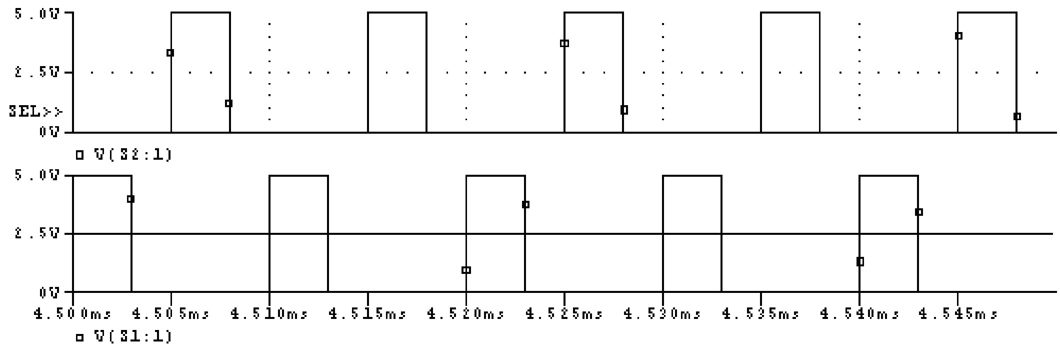

Fig. 2 Signal Waveforms for Forward Mode

In this reverse discharging mode of the switches S3 and S4 are turned on, Duty Ratio = PW / PER, =7.5/10 = 0.75 greater than 0.5 as the switching sequence given by the table 2. The diodes DS1 and DS2 are used for rectification purpose and the signal waveforms for reverse mode are shown in Fig.3.

Table 2. Switching Sequences of Switches S3 and S4

TIME PERIOD	S3	S4
$t_0 - t_1$	ON	ON
$t_1 - t_2$	ON	OFF
$t_2 - t_3$	ON	ON
$t_3 - t_4$	OFF	ON

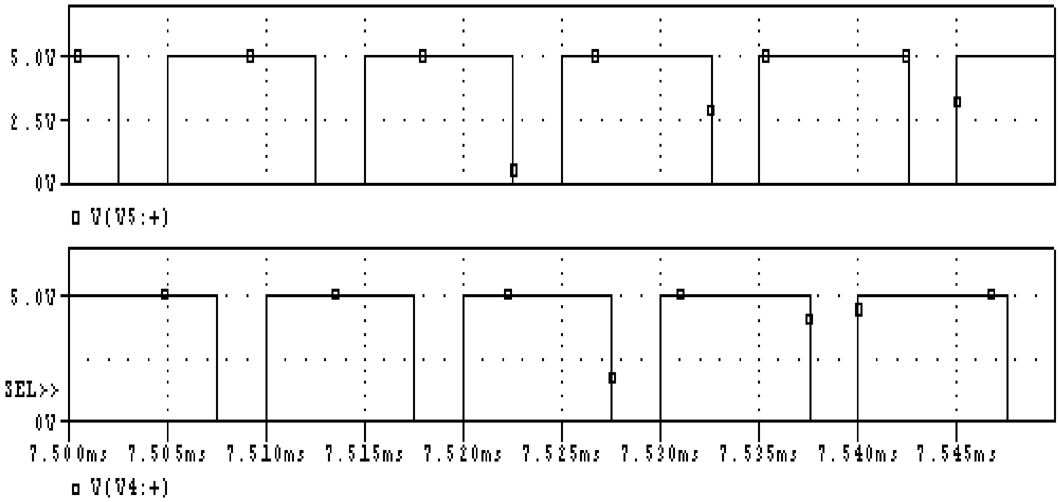

Fig. 3 Signal Waveforms for Reverse Mode

III. SIMULATION CIRCUIT AND WAVE FORMS FOR FORWARD CHARGING MODE

The circuit diagram of bidirectional dc-dc converter given in the paper was simulated using PSPICE. The driving pulses are given to the switches to turn them on and driving pulses are given as per the switching sequence. Here the winding NP1 is magnetically coupled with primary side of transformer using the linear coupled windings. When the main power input is functioning properly the converter could be operated as a battery charger. The circuit of forward charging mode simulated. During this mode the battery gets charged. The driving pulses are given to the switches S1 and S2 to turn them on. Then the battery voltage was measured across the resister. The simulation model for forward switching mode is shown in Fig.4.

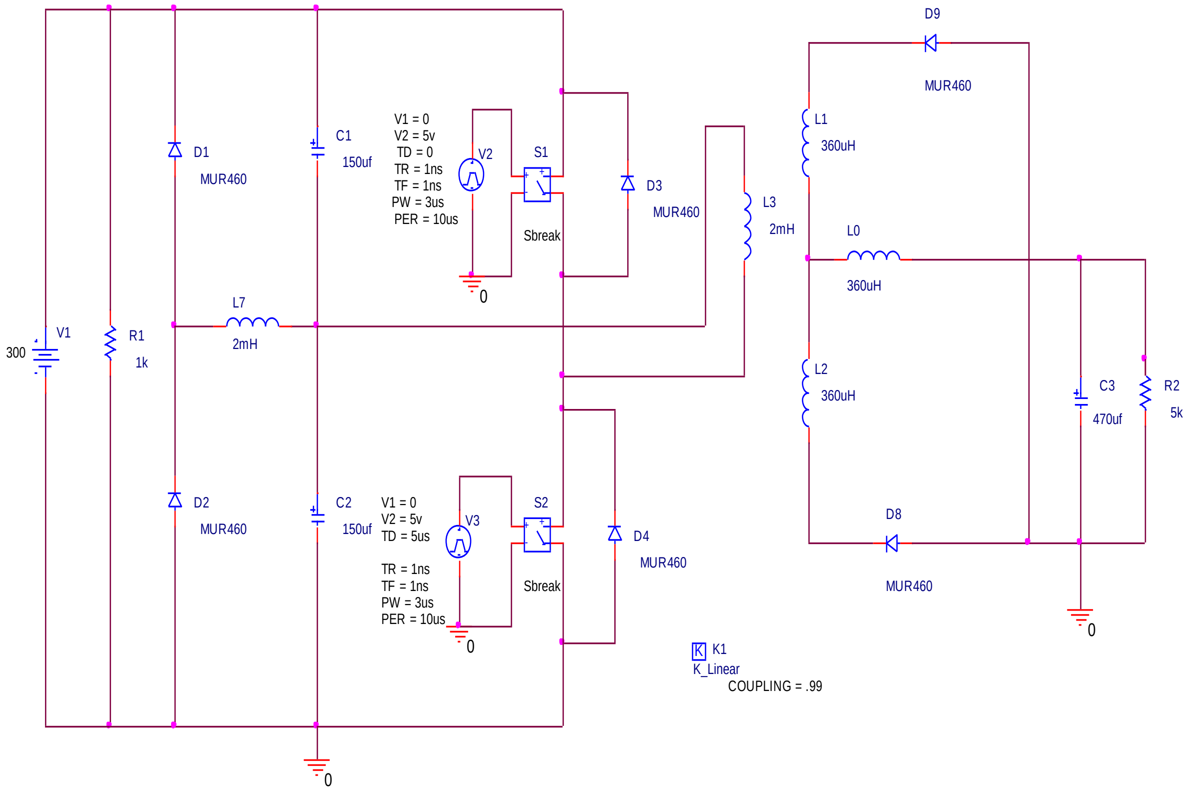

Fig. 4 Simulink model for Forward Charging Mode

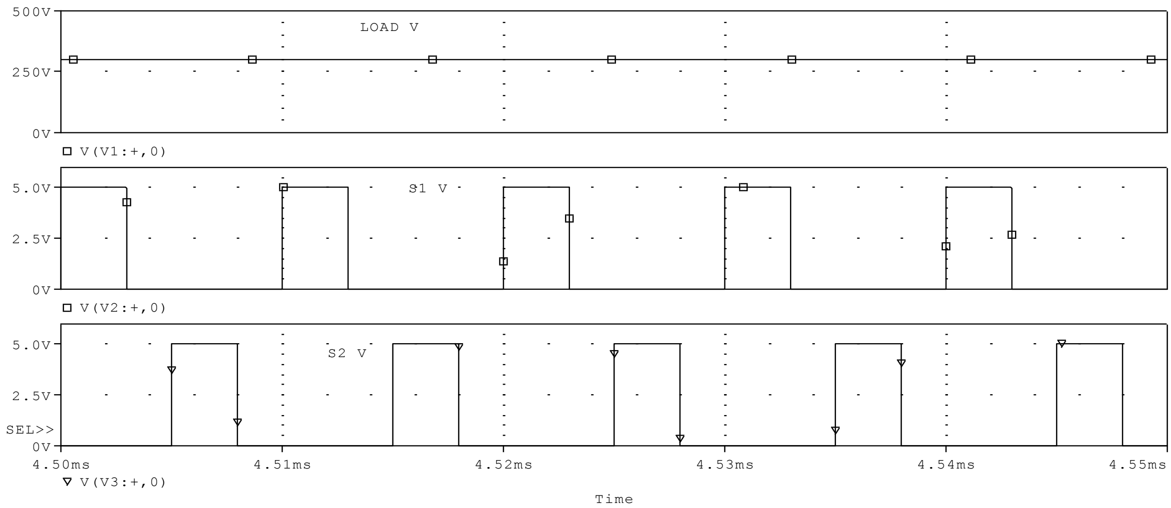

Fig. 5 Load Voltage and Voltage input to switches

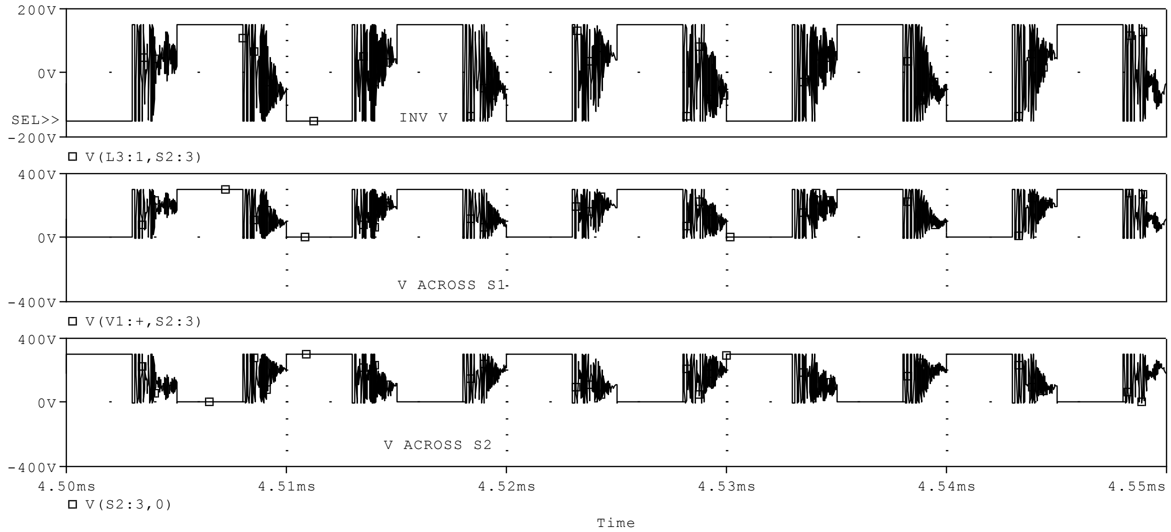

Fig. 6 Inverter Voltage and Voltage across switches

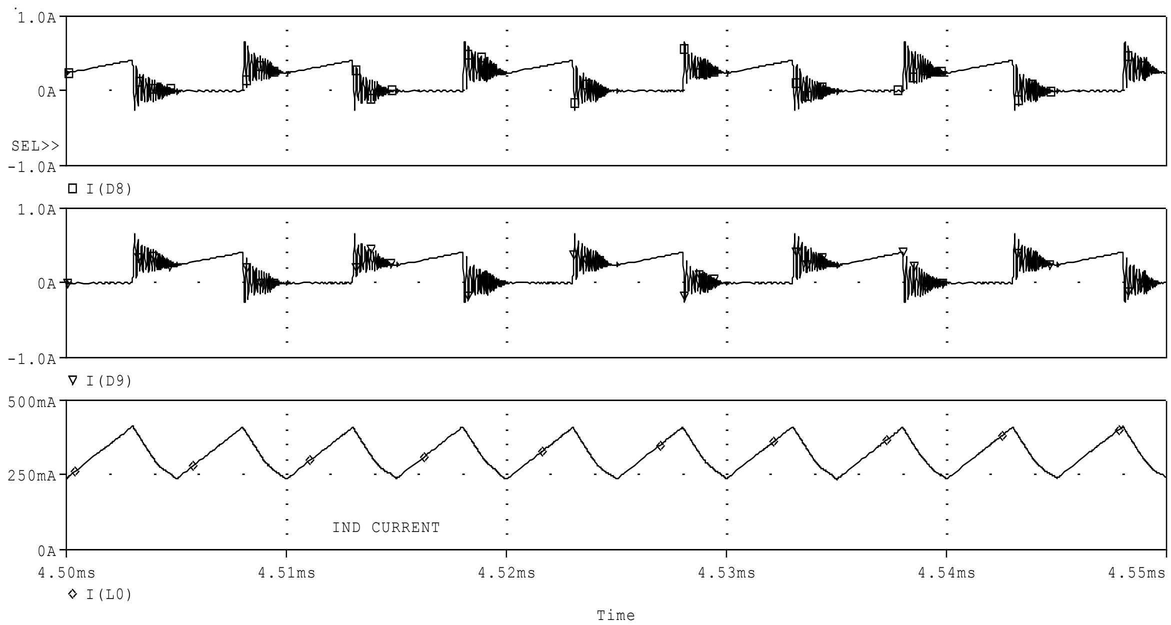

Fig. 7 Current through diodes and Inductor current

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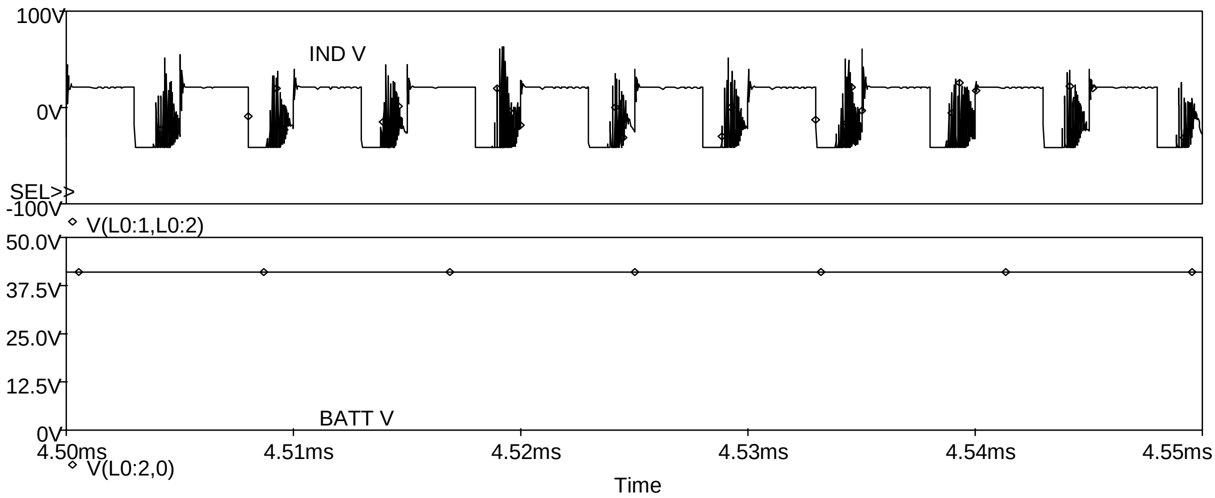

Fig. 8 Inductor voltage and Battery voltages

The simulation waveforms are shown in 5, 6, 7 & 8 which represents load voltage, voltage input to switches, inverter voltage, voltage across switches, current through body diodes of switches S3 and S4, inductor current , inductor voltage and the battery voltages respectively. From this waveform the battery voltage is 41V when 300V was applied at the input

IV. SIMULATION CIRCUIT AND WAVE FORMS FOR DISCHARGING MODE

The circuit of reverse discharging mode was simulated and the simulation model is shown in Fig. 9. During this mode the battery discharges the energy. The driving pulses are given to the switches S3 and S4 to turn them on. Then voltage across the load was measured.

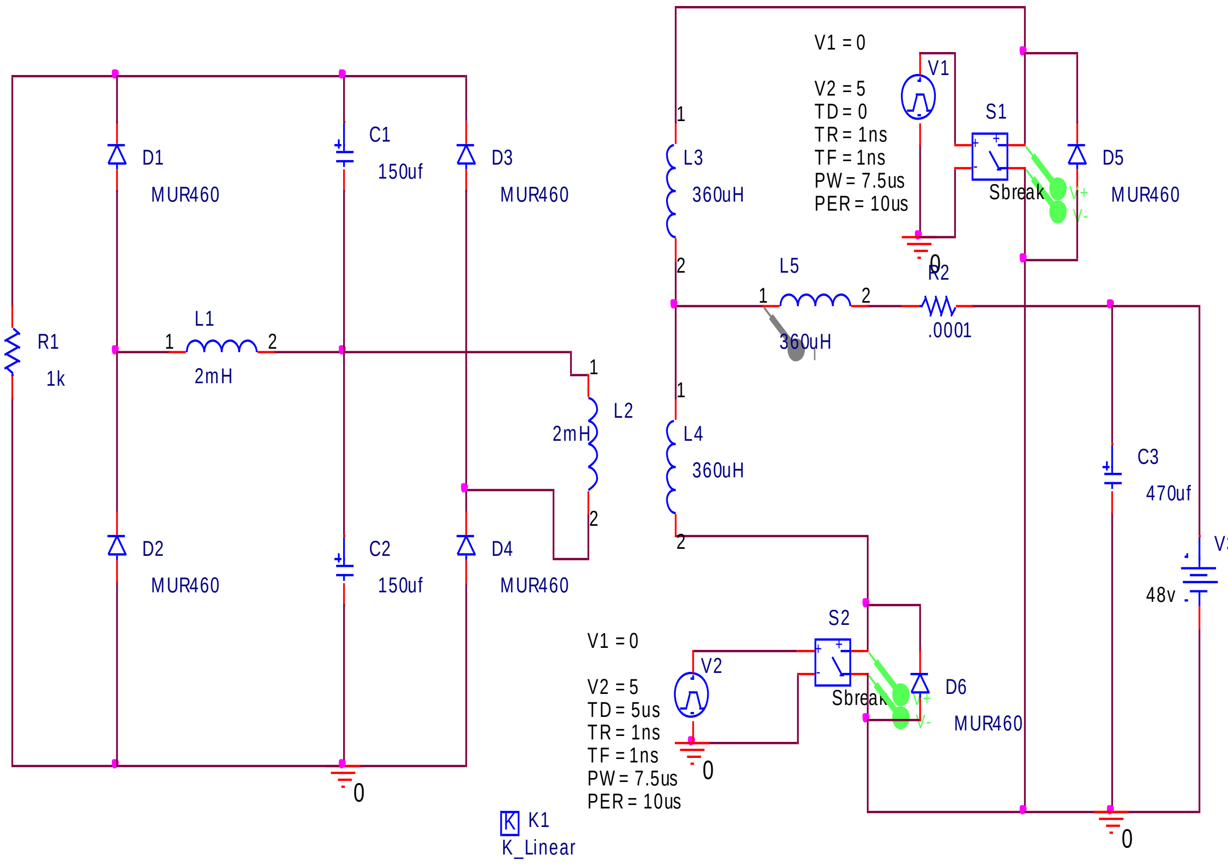

Fig: 9 Simulink model for discharging Mode

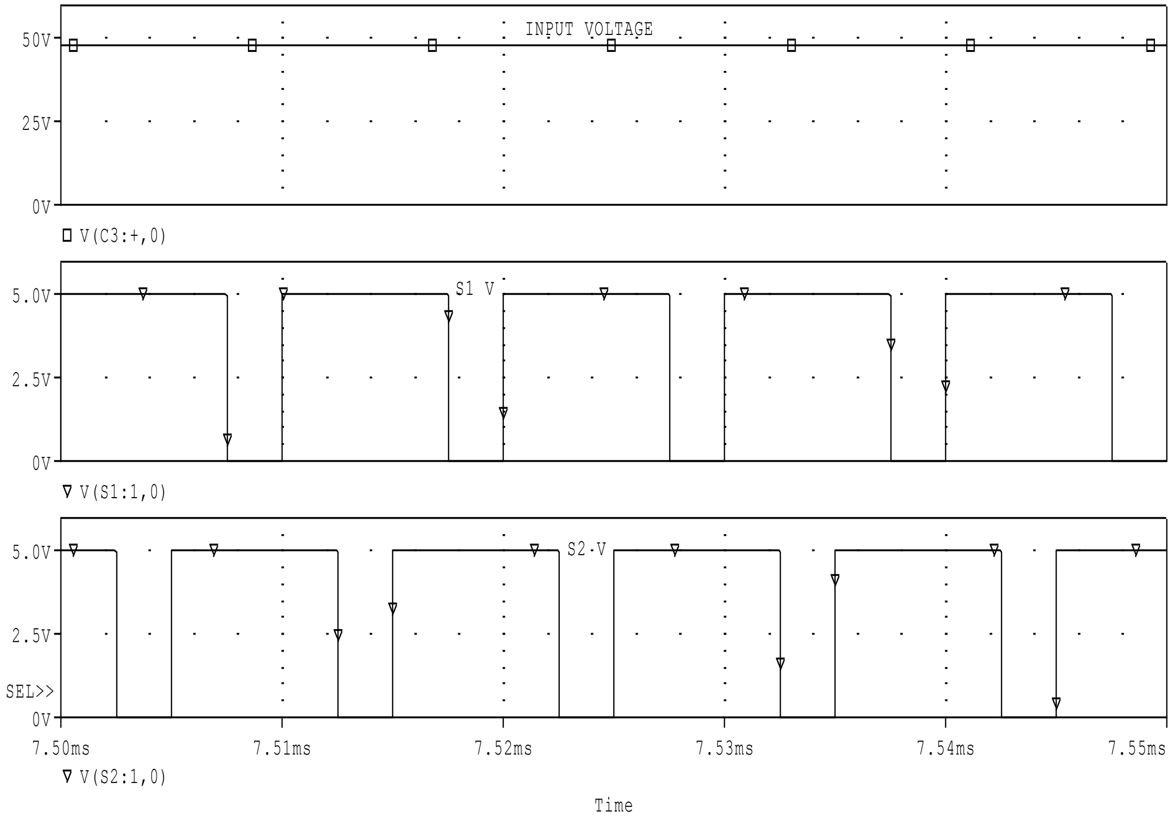

Fig. 10 Input Voltage and Voltage input to switches

The simulation waveforms are shown in Fig. 10 to Fig. 13 which represents input battery voltage, voltage input to switches, voltage across switches, inductor voltage, inductor current, load voltage, and inverter voltage respectively. From this waveform the load voltage is 120V when 48V battery was used.

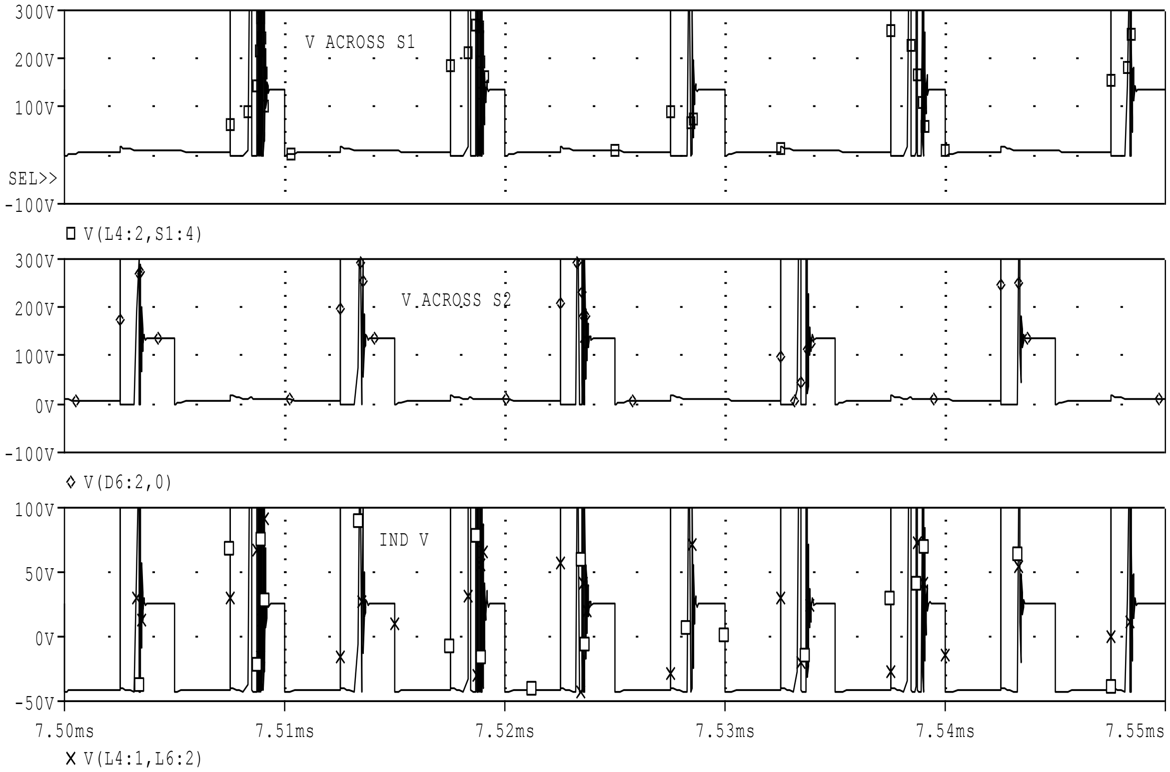

Fig. 11 Voltage across switches and Inductor Voltage

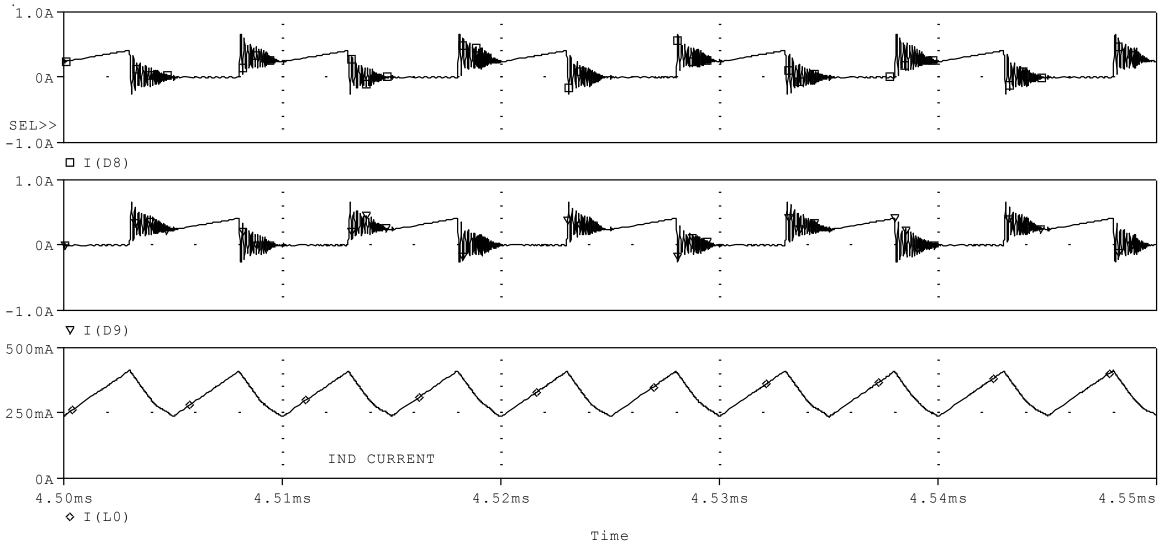

Fig. 12 Current through diodes and Inductor current

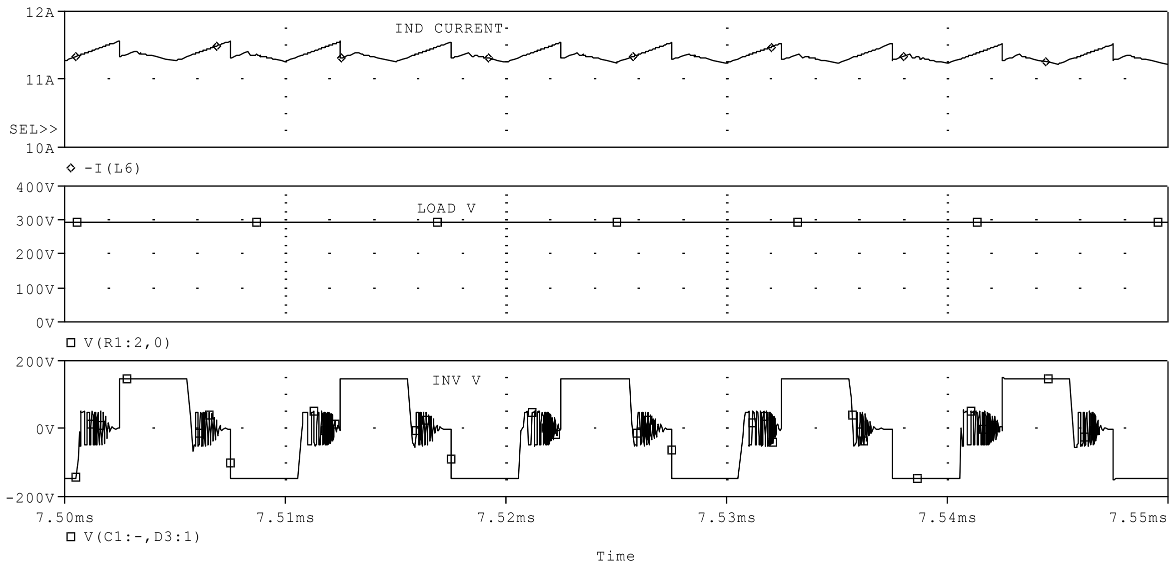

Fig. 13 Inductor voltage, Load voltage and Inverter voltage

V. HARDWARE IMPLEMENTATION

The converter topology transfers the power flow from dc source to battery while charging and from battery while discharging. This can be achieved by using rectifier, inverter and transformer with unity turns ratio and is shown in Fig.14

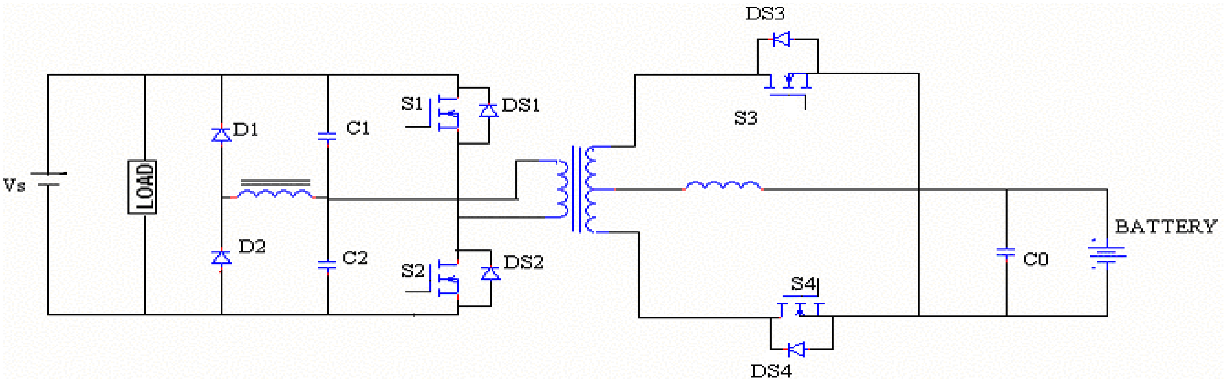

Fig. 14 Hardware Circuit

The transformer provides galvanic isolation between the dc mains and the battery. The primary side of the converter is a half bridge and is connected to the dc mains. The secondary side, connected to the battery, forms a current-fed push-pull. The fig shows a balancing winding Np1 and two catching diodes D1and D2 on the primary side of the half bridge. They maintain the center point voltage at the junction of C1 and C2 to one half of the input voltage. Here Np1 and Np windings are have same number of windings.

VI. CONCLUSION

The proposed converter has implemented and provides the desired reversible flow of power in a battery charger-discharger circuit which includes combining two simple converter topologies in a single power processing stage, enabling its operation in both modes. The integrated converter has only one high frequency transformer between low voltage battery and high voltage supply end. The hardware results show high steady state efficiency for both operating modes. The desired control techniques for the switches can be implemented in both modes by using a single PWM chip. The effect of soft switching on the performance and efficiency of the proposed converter topology can be improved by reducing circuit complexity.

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